Meteoritic Phosphides as a Source of Prebiotic, Reactive Phosphorus

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We present the results of an experimental study of aqueous corrosion of Fe-phosphide under conditions relevant to the early Earth. The results suggest that iron meteorites were an important source of reactive P leading to the formation of P-based life. We demonstrate that iron meteorites were an abundant source of phosphide minerals early in Earth history. Phosphide corrosion was studied in solutions of water, water with dissolved Mg- and Ca- chlorides, water with ethanol and acetic acid, and water containing the chloride salts, ethanol, and acetic acid. Experiments were performed under both air and pure Ar gas to evaluate the effect of atmospheric chemistry. Phosphide corrosion in de-ionized water results in a metastable mixture of mixed-valence, P-bearing ions including pyrophosphates and triphosphates. Corrosion in ethanol- and acetic-acid-bearing solutions yields additional organic molecules including acetyl phosphonate and a cyclic tri-phosphorus molecule. Phosphonate is a major corrosion product of all experiments and is the only P-bearing molecule that persists in solutions with high concentrations of divalent salts, suggesting phosphonate may have been a primitive oceanic source of phosphorus.

The stability of phosphonate and hypophosphite in solution was investigated to elucidate reaction mechanisms and the role of mineral catalysts on P-solution chemistry. Phosphonate oxidation is rapid in the presence of Fe metal but negligible under other conditions. The rate of hypophosphite oxidation is independent of catalyst.

We also present experiments attempting to phosphorylate glycolaldehyde using the corrosion products of the phosphide in solution relevant to the early Earth and to extraterrestrial bodies.